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Title: Studying dynamo and MRI in dusty plasmas

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Studying dynamo and MRI in dusty plasmas

Through machine learning of long-range correlated dust transport

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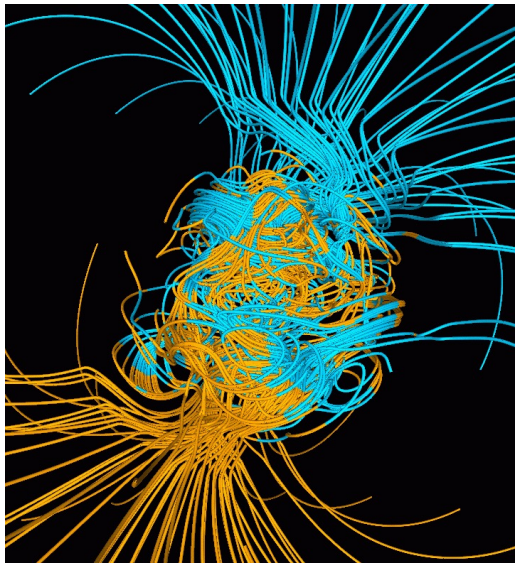
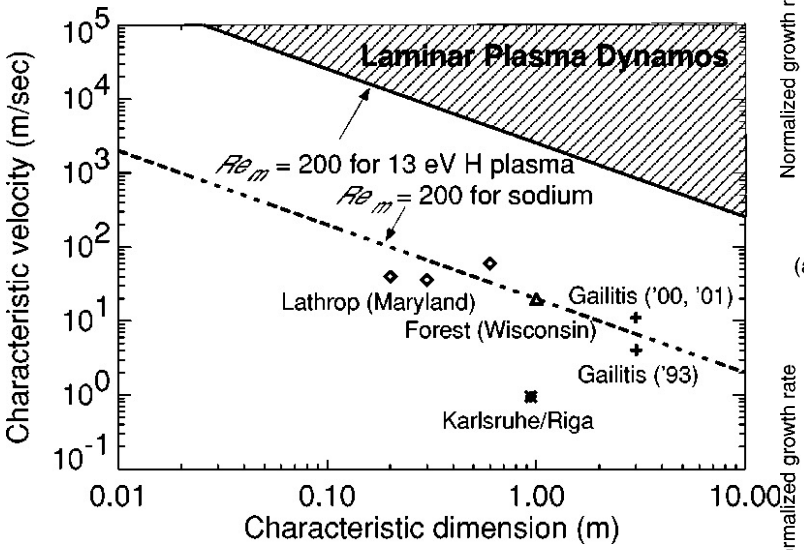
OUTLINE

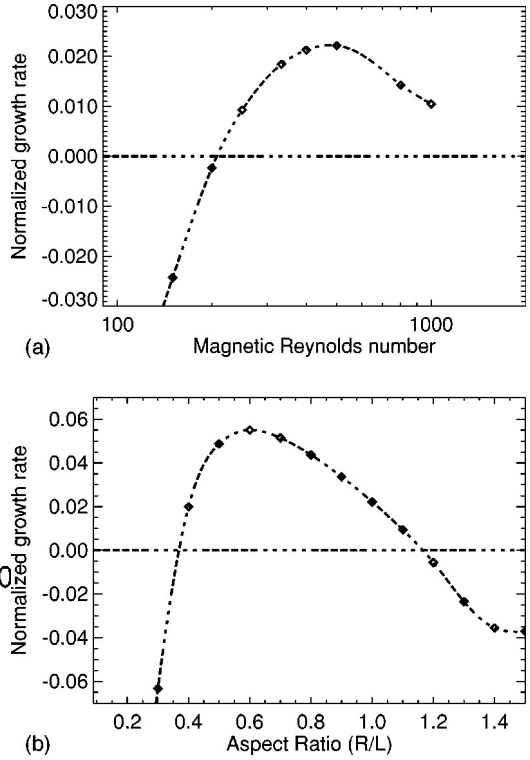
- Laboratory studies of dynamo & Magneto-Rotational Instability (MRI) mechanisms
- Dusty plasmas as a platform for laboratory astrophysics
- Machine Learning (ML) of dust trajectories and transport
- A possible initial experiment

Laminar Plasma Dynamos



Wiki: dynamo theory





Z. Wang, et al, Phys. Plasma. **9** (2002) 1491.

Magneto-rotational instability (MRI) in astrophysics

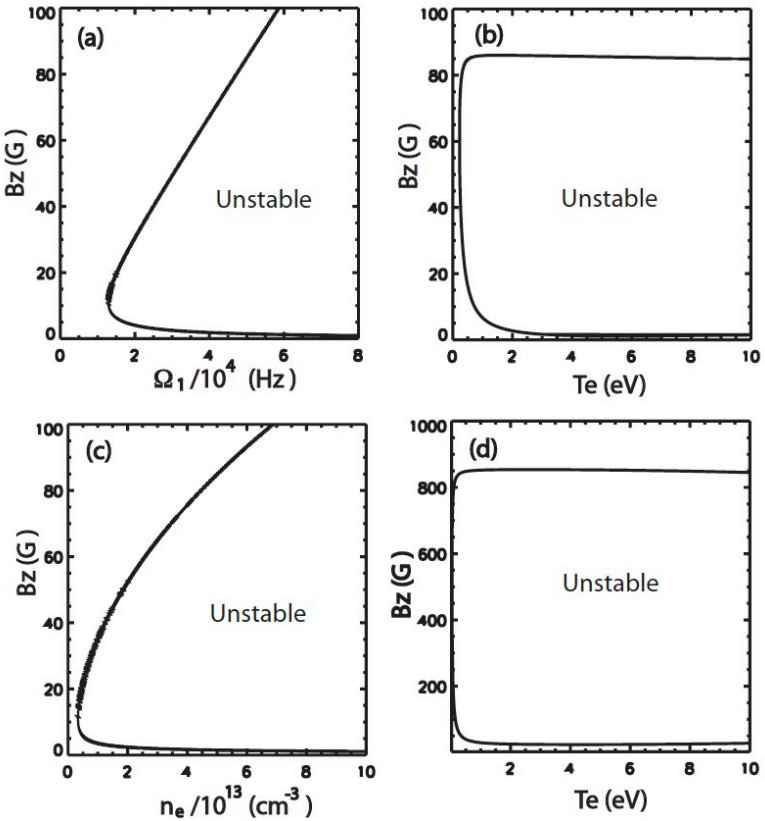
Hubble & Web images

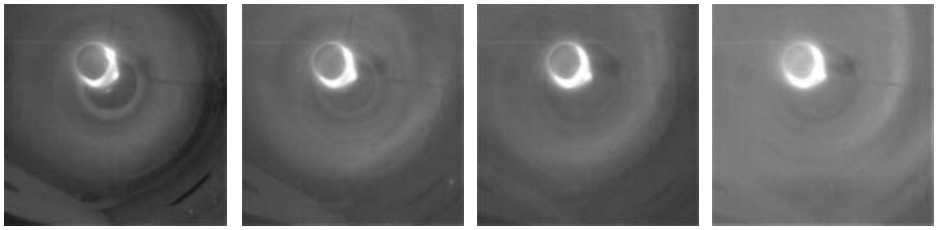
Mystery: The 'standard hydrodynamic & MHD models' are **insufficient** to explain the observed emissions (accretion rate, and luminosity)

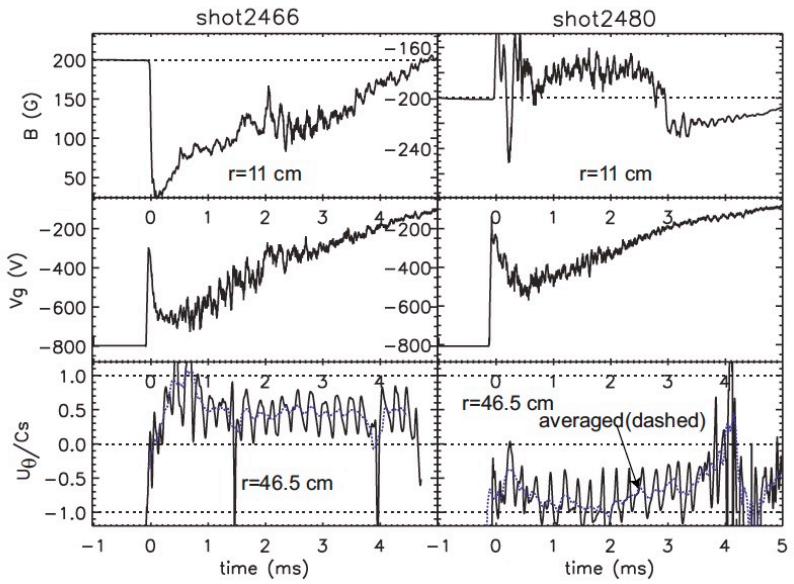
Theoretical breakthroughs motivate MRI:
E. P. Velikhov (1959);
S. Chandrasekhar (1960);
S. A. Balbus & J. F. Hawley (1991, 1998);

Opportunities: Laboratory validation of the physics mechanisms:
> Princeton/PPPL, Liquid Metal
> LANL, Plasma
> Wisconsin, plasma
…
>> Dusty plasma approach (this talk)

MRI in plasma Couette flows (LANL/FMP experiment)





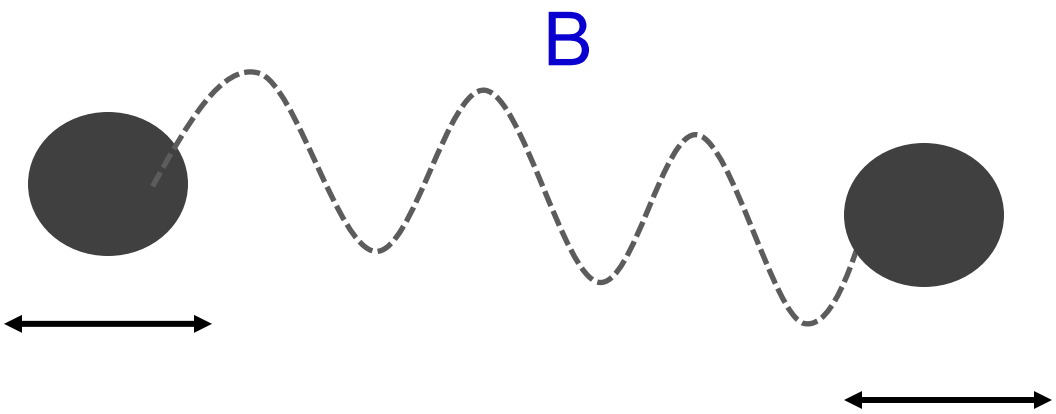


Z. Wang, et al, Phys. Plasma. **15** (2008) 120109.

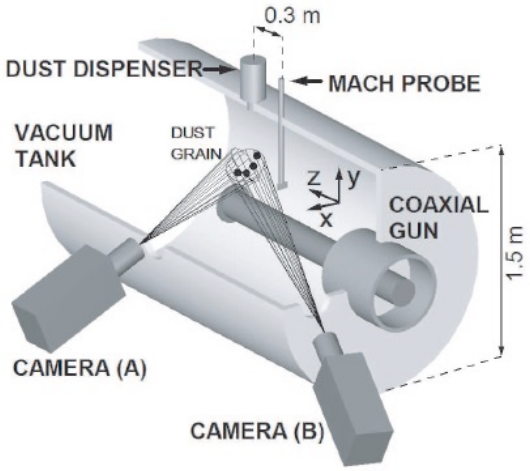
"It is so very easy to make mistakes in magneto-hydrodynamics that one should not believe in a result obtained after a long and complicated mathematical derivation if one cannot understand its physical origin; in the same way, one cannot also believe in a long and complicated piece of physical reasoning if one cannot demonstrate it mathematically."

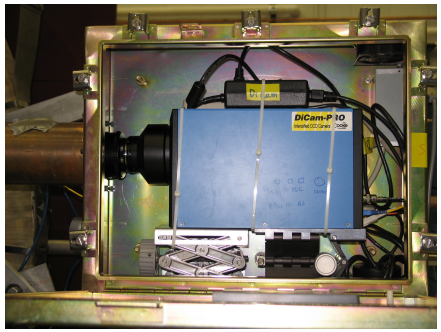
---- From E. Fermi, Collected Papers, Vol II, Univ. Chicago Press (1965), p. 925

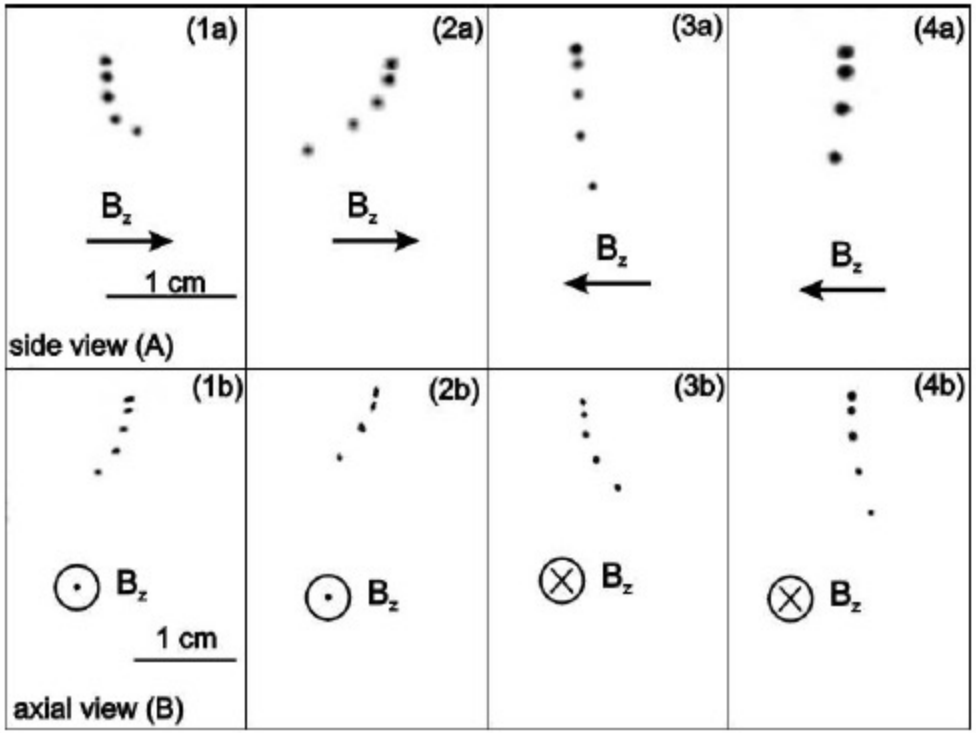
An overly simplified view of MRI



Dusty plasmas as a laboratory astrophysics platform





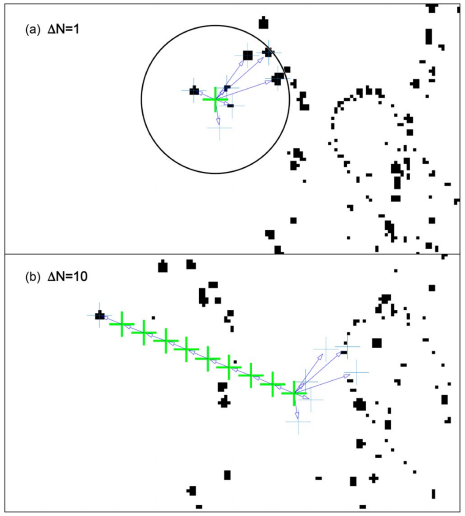


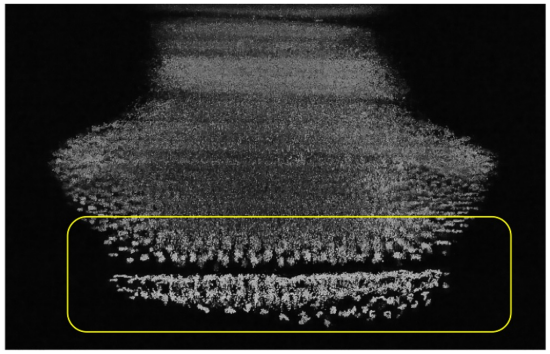
Cam A

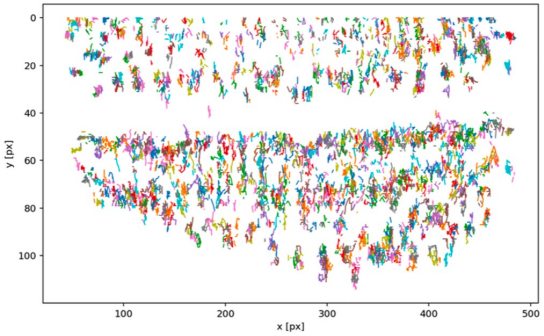
Cam B

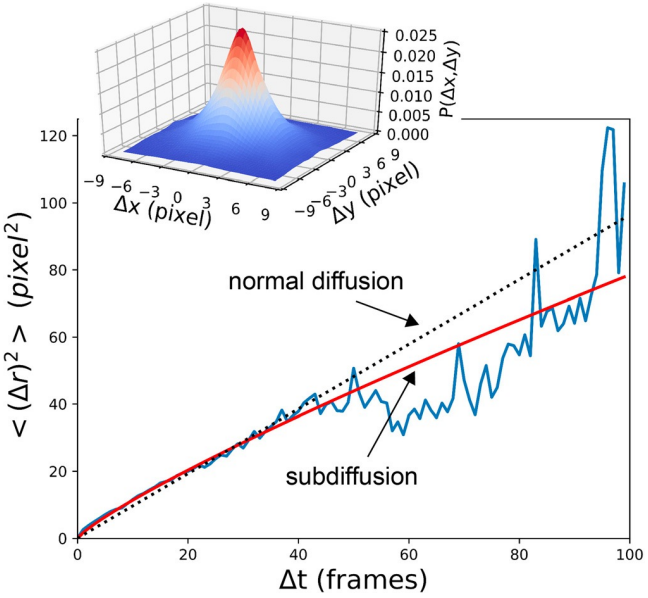
→ Particle tracking tools for a large number of particles
→ Introducing weak magnetic field to an existing exp.

Neural networks for particle tracking









Z. Wang, et al, Phys. Plasma. **27** (2020) 033703.

Summary

- **Dusty plasmas are promising new platforms for laboratory astrophysics**
  - Dynamo physics
  - MRI physics
  - Could be more (for example: Paul Bellan's talk from Caltech)
- **Such experiments will be empowered by ML methods that became available just recently**
- **Laboratory experiments pave the way towards ISS experiments/COMPACT in the near future**
  - Introducing weak magnetic field to an existing experiment as a first step.